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THERMAL ASPECTS OF LITHIUM-ION CELLS

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Objective of this investigation is to provide the necessary inputs for a thermal model of the Li-Ion battery for the Mars 2001 Lander. Two alternate configurations of this battery are under development: a) prismatic parallel plate, and b) cylindrical spiral wound. Required thermal inputs for both consist of the following: a) heat generation rates, b) thermal mass, and c) thermal conductivity. Thermal mass and conductivity were computed on the basis of known properties and configuration of the cell components. The heat generation rates were taken as the product of current and difference between open circuit voltage (OCV) and operating voltages (CCV) at a given state-of charge (SOC). Herein, it was assumed that the enthalpy voltage was equal to the OCV. OCV vs SOC data were obtained experimentally and CCV vs SOC were taken from previously obtained discharge data.

Heat Generation OCV's were determined as a function of SOC by measuring OCV first in the fully charged state and then after incremental discharge periods to the fully discharged state. These measurements were then repeated in the reverse direction during incremental charge periods from the fully discharged to the fully charged state. Figure 1 gives typical OCV results.

In a prior study, the heat was estimated by use of a linear relation of OCV and SOC. Herein we used the actual OCV vs SOC curves rather than a linear approximation of this curve. In either case, the heat was taken as the product of current and difference between OCV and CCV at a given temperature and SOC. Figure 2 gives typical cell CCV, OCV, and heat during constant current discharge @ 25°C at the C/2 rate (12.5 A). Figure 3 gives the calculated (as above) heat for this cell at 25° C at discharge rates of 2.5, 5.0, 7.5, and 12.5 A. The following points were noted: a) comparable heat rates were projected for both cell configurations, b) heat increases with increase in current and decrease in temperature. c) heat is not a strong function of SOC except near the points of full charge and discharge, d) heat is lower for charge than for discharge at comparable rates and any given temperature, and e) the highest heat rate for the indicated range studied was near 8 W for discharge at 12.5 A and at -20°C. Support for this method of estimating heat was given by noting agreement of integrated heat with measured energy loss over a cycle. Rates also agreed with measured heat rates on a smaller (3.8-AH D size) Li-Ion cell from in-house calorimetry studies.

Thermal Mass Thermal mass of a cell was taken as the summation of the products of it's component weights and specific heats Both configurations weigh near 0.8kg and have thermal masses near 200 cal/°C (830 J/°K).

Thermal Conductivity Effective thermal conductivity of the prismatic cell is near 1.2 W/M°K in the perpendicular direction to the stack and near 25 W/M°K in the parallel direction of the stack. Effective thermal conductivity of the cylindrical cell is near 1.8 W/M°K in the radial or perpendicular direction to the stack and near 27 W/M°K in the axial direction of the stack.

These inputs are being used in thermal modeling studies to establish that the battery thermal design is adequate to limit cell temperature range to that required for performance as well as safety for the mission.

Acknowledgement The work described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration

Figure One: OCV, CCV and Heat Generation of Prismatic Cell

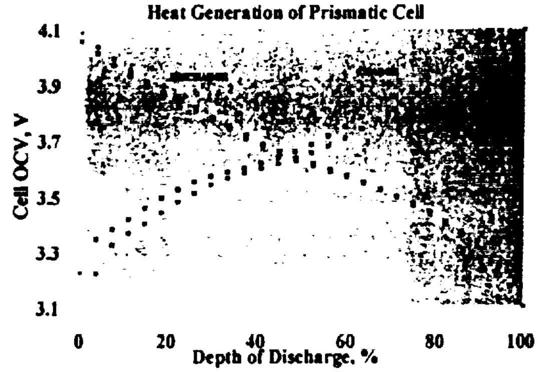

Figure Two: CCV, OCV and Heat Generation of Prismatic Cell at Room Temp.

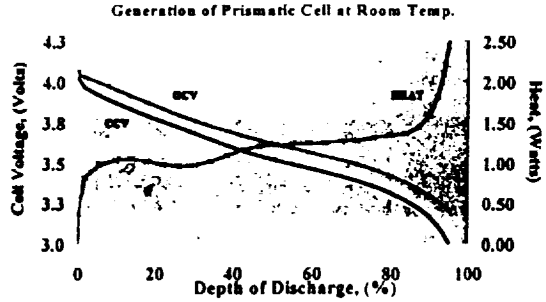

Figure 3: Heat Evolution During Discharge of Prismatic Cell at 25 Degrees and Four Rates